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REGIONAL TUNA TAGGING PROJECT PHASE 1: PAPUA NEW GUINEA

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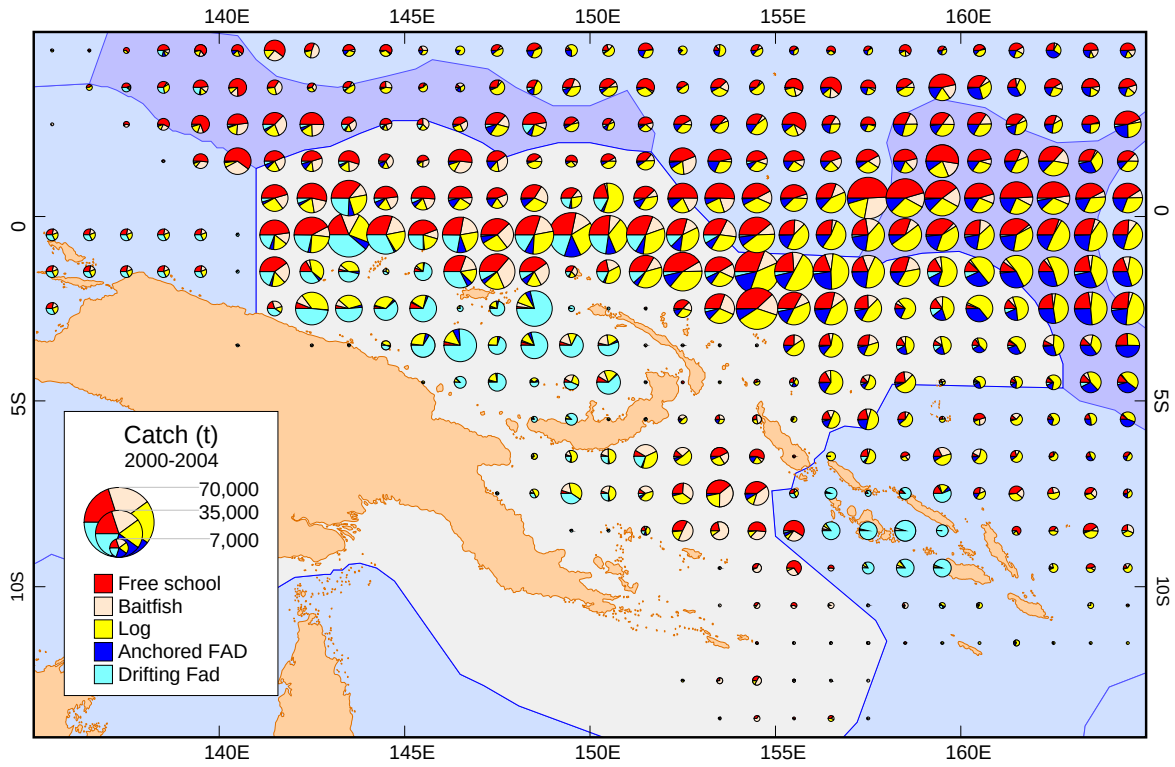
Regional Tuna Tagging Project
Phase I: Papua New Guinea



A proposal presented by:

the Oceanic Fisheries Programme of the Secretariat of the Pacific Community

and

the Papua New Guinea National Fisheries Authority

December, 2005

1. Title of the Project

Regional Tuna Tagging Project Phase 1: Papua New Guinea

2. Executing Agencies

Oceanic Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC) and the Papua New Guinea National Fisheries Authority (NFA).

3. Background to the Project and Justification

The tuna fishery in the western and central Pacific Ocean (WCPO) produces approximately half of the world's tuna and is of high economic importance to Pacific Island Countries and Territories. Throughout the WCPO, total annual catches of target tuna species (skipjack, yellowfin, bigeye and albacore tuna) are now approaching 2 million tonnes. The fishery comprises a variety of fishing activities, the most important of which are the industrial-scale purse seine, longline and pole-and-line fisheries. Large catches are also made by numerous small fishing vessels employing a variety of fishing methods in the adjacent waters of Philippines and Indonesia. While the overall fishery is distributed widely from about 40°N to 40°S, by far the majority of the catch occurs in equatorial waters between about 10°N and 10°S (Figure 1). In this region, catches are dominated by purse seiners, which catch mainly skipjack and yellowfin tuna, with a smaller catch of bigeye tuna. Purse seiners have two main operational modes – setting on free-swimming (or unassociated) schools of skipjack and medium-large yellowfin; and setting on schools associated with floating objects such as drifting logs and anchored or drifting fish aggregation devices (FADs). These associated sets tend to catch larger quantities of small, juvenile yel-

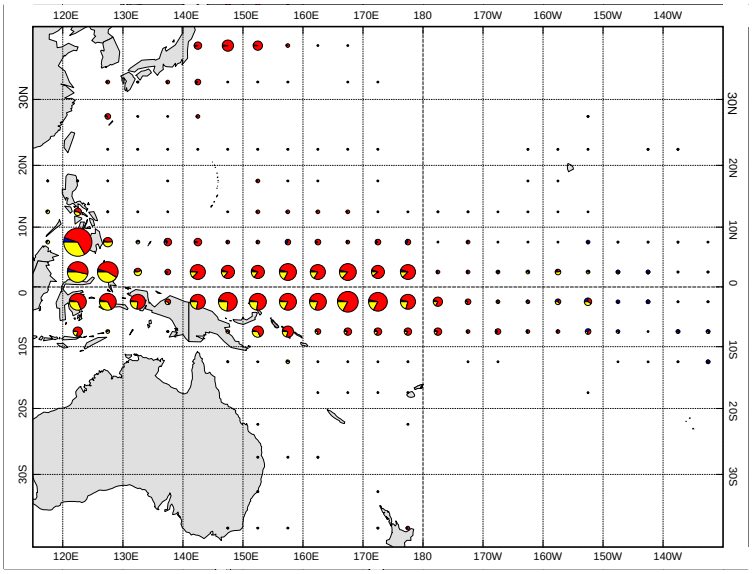


Figure 1. Distribution of skipjack (red), yellowfin (yellow) and bigeye (blue) tuna catch, 2000-2005.

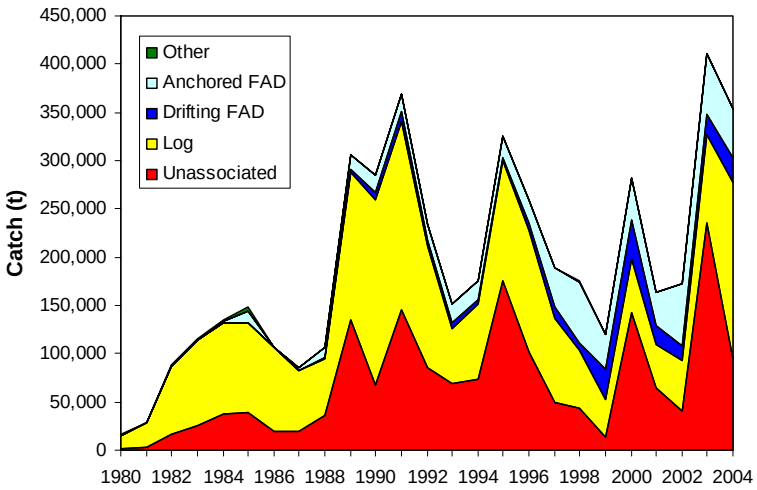


Figure 2. Purse seine tuna catch in the PNG EEZ by set type.

lowfin and bigeye tuna. Longliners target adult bigeye and yellowfin tuna in this region and at higher latitudes.

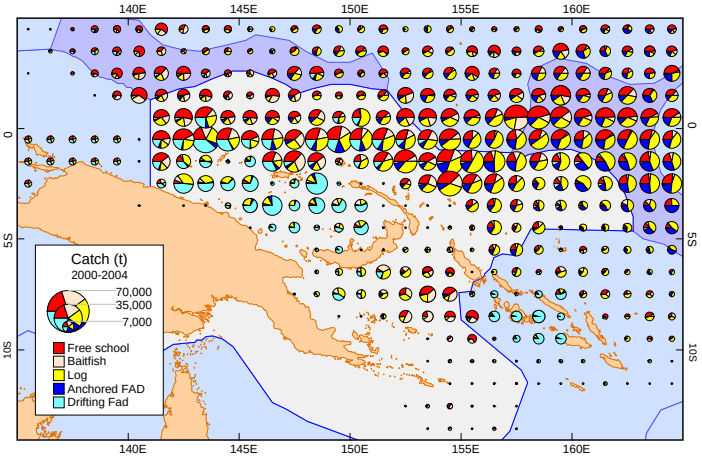


Figure 1. Distribution of purse seine catch by set type in the vicinity of PNG, 2000-2004.

Papua New Guinea (PNG) is an extremely productive tuna fishing area. Catches in the PNG exclusive economic zone have averaged about 250,000 tonnes per year over the past decade, peaking at approximately 400,000 tonnes in 2003. Most of this catch has been taken by foreign-licensed and locally-based purse seiners, although a locally-based longline fleet also operates in the southern part of the EEZ. The purse seine fishery in PNG is strongly dependent on sets on floating objects, in particular logs and drifting and anchored FADs (Figure 2, Figure 3). Therefore, a significant proportion of the catch consists of juvenile yellowfin and bigeye tuna. There is also significant by-catch of other species taken in these sets.

Regular assessments of the status of skipjack, yellowfin and bigeye tuna stocks are undertaken by the OFP. While skipjack tuna is considered to be in good condition, serious concerns regarding the status of yellowfin and bigeye tuna stocks, particularly in this equatorial region of the WCPO, are beginning to emerge. These assessments analyse catch, effort and size composition data from the fisheries, as well as available tagging data. While the fishery statistics are updated annually for the assessments, the most recent tagging data, which provide important fishery-independent information on fish movement, growth and mortality, dates back to the early 1990s.

Successive meetings of the Standing Committee on Tuna and Billfish, and most recently the inaugural meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission (WCPFC), have recommended that a new large-scale tagging project on all three species (but with particular attention to yellowfin and bigeye tuna) be carried out to reduce uncertainty in the assessments. Such a project would involve the large-scale tagging of skipjack, yellowfin and bigeye tuna throughout the area of operation of the major fisheries for these species in the WCPO (Figure 1). The major objective of such a project would be to improve the assessments of skipjack, yellowfin and bigeye tuna through the provision of information on medium- to large-scale movement characteristics and fishing and natural mortality rates. The tagging data generated by the project would be incorporated directly into the stock assessment analyses and contribute new information on these biological processes.

As a first phase of this regional project, it is proposed that tagging be conducted in the PNG EEZ using a chartered pole-and-line vessel. In addition to contributing to the regional objective outlined above, the Phase I activity would also address issues of specific importance to the management of the tuna fishery in PNG, including the estimation of local exploitation rates and increasing the understanding of the dynamics of tunas associated with FADs.

FAD fishing is also an issue at the regional level. Over the past decade, the deployment of drifting FADs by purse seiners has become a routine practice. FAD technology has also de-

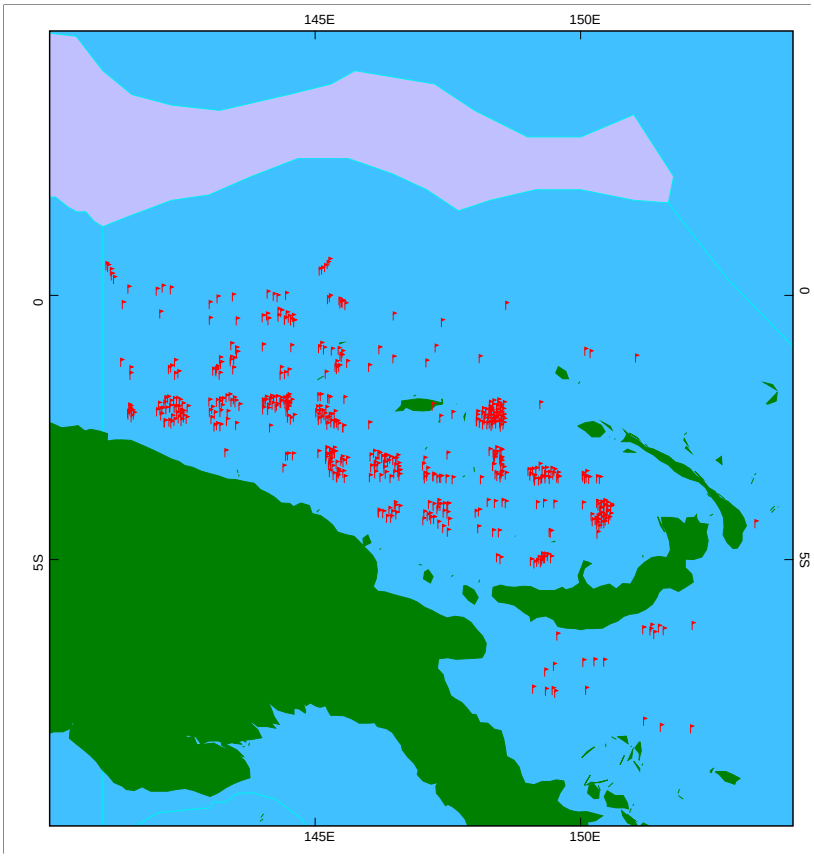


Figure 2. Anchored FADs deployed in the PNG EEZ.

veloped rapidly, with many operators deploying acoustic sensors on the FADs which they are able to interrogate remotely to estimate the quantities of tuna aggregated. These developments have greatly increased the efficiency of purse seining, increasing catches of skipjack and juvenile yellowfin and bigeye tuna. However the extent of efficiency increase is difficult to quantify as there is little information available on the dynamics of tuna attraction and residence on FADs. The existence of a large array of anchored FADs in PNG, which have been deployed over the past 10 years (Figure 4), provides an opportunity for detailed study of the behaviour of the associated tuna, which may yield important new information relevant to the management of FAD fishing in both PNG and the wider WCPO.

This proposal seeks funding support for the Phase I tagging activity in PNG waters. As noted above, the proposal addresses objectives specific to tuna fishery management needs in PNG, but would also constitute an important component of a new regional tuna tagging project. It is expected that additional donor support will be attracted once this Phase I project is implemented, allowing extension of the project to Phase II in other areas of the WCPO.

4. Objectives of the Project

The specific objectives of Phase I are:

1. **To obtain information on the large-scale movement of tuna in, and from, the PNG EEZ.** This information is important for understanding the relationship of PNG stocks with those of adjacent areas. Movement rates are particularly important for assessing the potential for interaction between fisheries operating in different areas. The comparison of tagged fish movements from the Bismarck Sea (the area of major anchored FAD deployment shown in Figure 4) that will result from this project with tagged fish movements from the same area in the early 1990s (before extensive anchored FAD deployment) will provide important new information on the meso- to large-scale effects on tuna movement of large anchored FAD arrays.
2. **To obtain information on current exploitation rates of tuna in the PNG EEZ.** Information on local exploitation rates is important for understanding the impact of fishing at the EEZ scale. In particular, it allows estimation of the extent to which current

catch levels may reduce the standing stock of tuna and the catch-per-unit-effort of the fisheries, a phenomenon commonly know as “local depletion”.

3. **To obtain information on the dynamics of tuna associations with FADs, in particular species-specific information on residence times, vertical and horizontal movements and FAD interactions.** This information is required for a better understanding of the effects of FADs on tuna stocks and their vulnerability to fishing, and for the design of appropriate management measures.

4. **To obtain data that will contribute to regional tuna stock assessments.** Conventional tagging data are an important component of tuna stock assessments, providing quasi-fishery-independent information on exploitation rates, natural mortality, movements and other parameters.

5. **To obtain information on the trophic status of free-swimming schools of tuna, and tunas associated with FADs, other floating objects and seamoun**ts. This information is required for the general understanding of the ecosystem impacts of FADs compared to other types of tuna aggregations.

6. **To characterize the variability and extent of catches of by-catch species from purse seine catches in PNG.** NFA runs an observer programme with high coverage rates, which offers the opportunity to document by-catch levels and their variability in purse seine sets on anchored FADs and other set types.

5. Anticipated Outcomes pf the Project

The anticipated outcomes of Phase I are:

1. The updated information on tuna stock dynamics in PNG arising from objectives 1 and 2, including estimates of stock size and exploitation rates, would better guide future management decision-making in PNG, in particular the recommendation of total allowable catches and/or effort.

2. The information on the dynamics of tuna associations with FADs arising from objective 3 would allow a more scientifically-based FAD-deployment policy in PNG. If differences in species behaviour at FADs are detected, it is possible that management measures can be designed that exploit those differences to reduce the catches of juvenile yellowfin and bigeye tuna while minimizing and negative impacts on catches of skipjack tuna. This would have a positive impact on yellowfin and bigeye tuna conservation and optimal exploitation not only in PNG but throughout the WCPO region. The results of the project will also provide information on FAD interaction, which will allow advice to be given to the NFA and fishing industry on the optimal spacing of FADs.

3. Phase I will also contribute data for regional tuna stock assessment in the form of conventional tag release and recapture data (objective 4). Such data should have considerable impact on the assessments, in particular by reducing uncertainty regarding recent levels of fishing mortality in the western equatorial sub-region of the assessments.

4. The information on trophic status of tuna in various types of association arising from objective 5 would contribute to the understanding of the impact and significance of FADs, other floating objects and seamounts on the pelagic ecosystem of the western tropical Pacific. This enhanced understanding would lead to a better scientific basis for the application of the ecosystems approach to fisheries management both in PNG and in the wider WCPO.

5. Information on the extent and variability of purse seine by-catch arising from objective 6 would allow a preliminary assessment of the impact of the fishery on various by-catch species and the development of appropriate management responses.

6. The involvement of NFA staff in the project would provide significant opportunities for training and national capacity building.

7. The success of this Phase I project would encourage donors to support Phase II, in which the field operations would move to other areas of the WCPO.

6. Project Activities

Planning

The centre-piece project activity will be the tagging and release of skipjack, yellowfin and bigeye tuna using a combination of conventional (numbered plastic dart tags) and electronic tags. The principal tagging platform will be a chartered Japanese-style pole-and-line vessel fully crewed and equipped for pole-and-line fishing and tropical bait fishing using *bouke ami* (dipnet) gear. Pole-and-line is the most suitable fishing method for tuna tagging because the fish are captured, tagged and returned to the water within a short time, usually less than 15 seconds. Pole-and-line also captures tuna of a similar size to purse seine and so is able to sample the population of tuna vulnerable to purse seining.

Prior to embarking on the fieldwork, considerable planning will be necessary for most aspects of the project, including:

- detailed design of the tag release programme using computer simulation methods;
- administering tendering procedures and/or direct negotiations for the charter of a suitable pole-and-line vessel;
- overseeing any modifications to the vessel that may be required for tuna tagging;
- obtaining the necessary permits to operate in PNG;
- organizing access to suitable bait grounds;
- selecting and training of PNG staff participating in the field work;
- purchase of necessary equipment, including tags and related equipment, fishing gear, biological sampling equipment, etc.;
- planning tag-recovery arrangements (see below), including organisation of publicity, industry briefing, training of port samplers, establishing in-port procedures for tag collection and reward payment, etc.

A coordinator will be contracted by the project to assist the OFP with the above tasks.

Tag releases

We will aim to tag approximately 30,000 tuna (~ 60% skipjack, 30% yellowfin, 10% bigeye) with conventional tags in six months of vessel operations. Tagging would be concentrated in the main area of the purse seine fishery (Bismarck Sea, Solomon Sea and adjacent areas) and cover tuna associated with anchored and drifting FADs, floating logs, seamounts and unassociated schools. The conventional tagging will address objectives 1 - 4 above.

During the tagging cruises, smaller numbers of the three species will be tagged with electronic tags to record more detailed information. Approximately 300 tuna (100 of each spe-

cies) will be tagged internally with archival geolocation tags. Releases will be targeted from different types of schools, including FAD-associated, seamount-associated and unassociated schools. Recaptures of these tags will provide detailed and virtually continuous information on swimming depth, ambient temperature, body temperature and light levels. The light and water temperature data will be used in geolocation algorithms to provide estimates of daily geographic location of the tagged fish with accuracy of 2 degrees of longitude and 5 degrees of latitude or less. This will allow an assessment of meso- to large-scale dispersal characteristics of the fish. The swimming depth and ambient temperature data will document the continuous vertical movements of the fish and will, amongst other things, provide an indication of species- and size-related differences in vertical movement behaviour. Based on similar work undertaken in the eastern Pacific, it is anticipated that behavioural patterns characteristic of different types of aggregation will be discriminated. The archival tagging will address objectives 1 and 3.

Approximately 300 tuna (100 of each species) will be tagged with acoustic transmitting tags in the vicinity of anchored FADs. Up to 50 receivers will be deployed on FADs (and possibly on seamounts) using methods developed by researchers at the University of Hawaii on FADs anchored around the main Hawaiian Islands. The receivers will detect the presence of tagged fish within a 1 km radius of the FADs (seamounts). Additionally, the tags will transmit depth during periods when the fish is within range of a receiver. These tags will therefore provide detailed information on the frequency, timing and duration of FAD (seamount) visitation by individual fish, and information on their swimming depth while at the FAD (seamount). Receivers and tagged fish will be strategically distributed across the anchored FAD array to provide information at a range of spatial scales. This work will address objective 3.

Biological sampling

The tagging cruises will present opportunities to collect stomach and tissue samples for trophic analysis from tuna that are not tagged (objective 5). Samples will be collected from all species captured across all school associations and, as far as possible, across a wide size range. A sampling design will be developed for this work. Stomach and tissue samples (for carbon and nitrogen isotope analysis) will be frozen and transported back to Noumea for analysis or forwarding to specialist laboratories. This work will specifically address the question of the impact of FADs on the nutritional status of aggregated tunas. This aspect of the work will be supported by an existing OFP project.

Tag recoveries

Conventional and archival tagging projects rely on recaptures by the fishery to provide information. Industry cooperation, particularly in PNG where most recoveries are likely to occur, is therefore essential. We will undertake the following steps to ensure high reporting of recaptured tags:

- Recovery procedures will be established in major tuna landing ports in PNG and elsewhere in the region utilizing, for the most part, established catch monitoring programmes. Industry briefing, publicity, tag-reward payment and data collection will be focused through individuals identified in each location.
- A publicity campaign will be mounted throughout the region to publicise the project. Publicity will occur via tagging posters distributed to landing ports and processing facilities, announcements in local news media and personal contact of project staff with the fishing industry and local communities. A website will also be established for the purpose of disseminating publicity and information about the project, and possibly as a means of collecting tag-recovery data.

- Rewards for the return of tags will be paid to tag finders. For conventional tags, a reward of US$10 per tag return will be paid. For archival tags, a reward of US$250 for each tag return will be paid. For acoustic transmitting tags, a reward of US$100 for each tag return will be paid. These differential rewards reflect both the value of the hardware and of the data accompanying the tag. Assuming that there is complete reporting of the higher value tags, any significant differences in return rates between conventional and electronic tags might be attributable to non-reporting (of conventional tags). This information will be important for subsequent modeling of the tag-return data.
- Tag-seeding experiments (surreptitious tagging of dead fish) will be undertaken by observers on purse seine vessels operating in PNG waters. The return rates of seeded tags are, subject to various conditions, indicative of the reporting rates of similar tags from the regular tagging programme. These experiments will be designed to provide statistically reliable information on tag reporting throughout the duration of the tagging programme.

Data processing and analysis

Data processing and analysis will be undertaken at SPC headquarters using existing technical and scientific staff resources. Conventional tagging data will be entered into the OFP's existing tagging database, in which the data from SPC's previous tagging programmes, and those of several other national programmes in the WCPO, are stored. Similarly, the data from returned archival tags will be downloaded and incorporated into an existing archival tagging database maintained by the OFP. The NFA will be given access to all data collected by the project.

Data collected by receivers placed on FADs will need to be downloaded periodically to avoid memory overflow. Initially, the tagging vessel will undertake this task; however the assistance of fishing companies will be required for longer-term servicing of the FAD receivers. Preliminary discussions have been held with one of the fishing companies in PNG that deploy and maintain anchored FADs (RD Tuna Canners Ltd), and they have indicated that they would be willing to cooperate with the project in this matter.

Several types of analyses of tagging and other data are envisaged, which would lead to scientific papers or reports published in an appropriate form. Analyses will be undertaken collaboratively with NFA staff and other scientific collaborators involved in the project (see section 10). The analyses envisaged include:

- Analysis of conventional tagging data using spatial models that may include the presence of FADs (e.g., Kleiber and Hampton 1994; Sibert et al. 1999; Sibert and Hampton 2003) and seamounts;
- Application of tag-attrition models (e.g., Hampton and Gunn 1998; Bertignac et al. 1999) to estimate local exploitation rates in PNG from conventional tag-return data;
- Incorporation of conventional tag-return data into regional stock assessment models;
- Estimation of horizontal movements from archival tag data using the light and temperature data collected by the tags (e.g., Schaefer and Fuller 2002; Nielsen et al., in press);
- Estimation of vertical movement behaviour and habitat preferences from the depth and temperature data collected by archival tags (e.g., Schaefer and Fuller 2002; Evans et al. 2005);

- Estimation of FAD (and possibly seamount) visitation frequency, residence times and movements throughout the anchored FAD array from acoustic tag – FAD receiver data (e.g., Itano et al. 2005);
- Characterisation of by-catch levels and their variability by purse seine vessels fishing on different types of school associations in PNG.

As well as the scientific publications and reports arising from the above, project information will be consolidated and interpreted for management purposes in a PNG National Tuna Fisheries Status Report.

Capacity building

Considerable capacity-building spin-offs are anticipated through the involvement of NFA staff in all aspects of the project, including project planning, fieldwork, interpretation of data and the development of fishery management recommendations.

7. Time Schedule

The following time schedule is proposed:

Project Activity	2006				2007				2008				2009			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Planning	X	X														
Equipment purchase	X	X														
Field operations			X		X											
Data processing			X	X	X	X	X	X	X	X	X	X	X	X	X	X
Interim report						X										
Data analysis							X	X	X	X	X	X	X	X	X	X
PNG NFSR*								X								X
Scientific papers													X	X	X	X
Phase II (prov.)							X	X	X	X	X	X	X	X	X	X

* National Fisheries Status Report

8. Budget

The following indicative budget has been formulated:

Budget Item	USD
1. Vessel charter (6 months @ $150,000)	900,000
2. Vessel modifications	50,000
3. Contract coordinator (9 months @ $10,000)	90,000
4. Field personnel (6 months @ $10,000)	60,000
5. Travel	60,000
6. Tagging equipment	569,000

7. Miscellaneous equipment	50,000
8. Tag rewards	81,000
9. SPC overhead on new funding	63,000
TOTAL	**1,890,000**

Budget Notes

1. Vessel charter costs are based on expected maximum catches by a tropical pole-and-line vessel and approximate current fish prices. Actual charter costs will depend on many factors and will be strongly influenced by fuel prices at the time. Charter will be subject to competitive tender and/or direct negotiation if the available candidate vessels are limited in number.
2. A nominal allowance for vessel modification is included. Modifications may be necessary to configure the vessel for scientific tagging and may include items such as accommodation for scientists, gear storage areas, biological sampling wet laboratory, etc.
3. A contracted project coordinator is required to assist with planning, logistics and general project implementation. This is budgeted at standard medium-term consultancy rates.
4. One or more experienced field biologists are required to lead the field operations. This is budgeted at standard medium-term consultancy rates.
5. Travel costs are estimated based on the equivalent of 20 round-trips Noumea-PNG-Noumea plus incidentals.
6. Tagging equipment is costed on the basis of 30,000 conventional tags @ $0.675, 1,000 tag applicators @ $6.75, 300 archival tags @ $1,100, 50 FAD receivers @ $1,100, 300 acoustic tags @ $490 and $10,000 for supplementary equipment, including computer hardware and software for electronic tags, tagging cradles, etc.
7. Miscellaneous equipment includes specialist fishing and fish-finding equipment and biological sampling equipment.
8. Tag rewards are estimated on the basis of a 20% tag recovery rate for all tag categories, and rewards of $10, $250 and $100 for conventional, archival and acoustic tags, respectively.
9. SPC is required to charge a 7% project management fee on all new funding. Contributions from Pacific Island countries and territories (e.g. PNG) are exempt from this fee. The sum shown is in respect of contributions confirmed or expected by ACIAR/AusAID, NZAID and the University of Hawaii. Contributions from the GEF and EC projects are separate line items on these projects and the management fee is deducted separately. See Section 10 for details of confirmed and expected funding.

9. Monitoring and Evaluation

The project will be monitored and evaluated according to established SPC procedures, including:

- Project activities will be incorporated into the OFP's 2006 and subsequent annual work plans and reported in the annual work programme reports;
- The results of the project will be reported to SPC Heads of Fisheries meetings and WCPFC Scientific Committee meetings held during the course of the project;
- Financial reporting for the project will be incorporated into the annual programme reports, in budget reports to SPC's governing council (the Committee of Representatives of Governments and Administrations) and individually to donors as required;
- Peer review of the results of the project will occur through publication in the peer-reviewed scientific literature; and

- Regular progress reports on the project will be made available on the project web site to be established.

10. Partners

In terms of project implementation, the main partners in the project are the SPC Oceanic Fisheries Programme and the PNG National Fisheries Authority. However, we will also be collaborating with the University of Hawaii on several aspects of the project, notably the deployment of FAD receivers, the associated acoustic tagging and the analysis and publication of results from this activity.

In terms of project funding, a number of donors are contributing to the project. These include the PNG National Fisheries Authority, the Australian Centre for International Agricultural Research, the New Zealand Agency for International Development, the University of Hawaii and the French Pacific Fund. In addition, existing SPC-executed projects funded by the Global Environment Facility and the European Commission will also contribute, consistent with the objectives of those projects.

11. Support for the Project

Regional tuna tagging is supported as a priority research activity by the SPC and by the WCPFC Scientific Committee. The PNG National Fisheries Authority and the tuna industry is strongly supportive of project, as evidenced by the USD 100,000 contribution approved by its Board of Directors (comprising representatives of the PNG Government, fishing industry and business community). Other funding partners are noted in section 10.

12. Other Related Activities

SPC implemented a regional tuna tagging project in the late 1980s and early 1990s, funded by the European Commission at a level of about USD 4,000,000. The project released approximately 150,000 tuna tagged with conventional tags and received approximately 20,000 recoveries. The data generated by this project has formed an important input to regional tuna stock assessments and has provided important baseline information on tropical tuna movement, mortality and longevity.

The present project, while addressing specific tuna fishery management issues in PNG, is expected to be the first phase of a new regional tuna tagging project that will immediately follow the PNG activity. Phase II is expected to have a budget in the vicinity of USD 5,000,000 and several significant funding commitments are already in place. It is anticipated that further Phase II funding will be obtained through voluntary contributions by WCPFC members.

13. References

Bertignac, M., J. Hampton, and A. L. Coan. 1999. Estimation of North Pacific albacore (*Thunnus alalunga*) exploitation rates from tagging data. *Fish. Bull. U.S.* 97:421–433.

Evans, K., N.P. Clear, T. Patterson, J. S. Gunn, and J. Hampton. 2005. Behaviour and habitat preferences of bigeye tuna (Thunnus obesus) tagged in the western Coral Sea. WCPFC-SC1, BI WP-7. http://www.spc.int/OceanFish/Html/WCPFC/SC1/pdf/SC1_BI_WP_7.pdf

Hampton, J. and J. Gunn. 1998. Exploitation and movements of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*T. obesus*) tagged in the north-western Coral Sea. *Mar. Freshw. Res.* 49:475-489.

Itano, D.G, L.C. Dagorn, and K.N. Holland. 2005. The use of FADs to monitor the behaviour and movements of tuna, billfish and pelagic sharks. WCPFC-SC1, BI WP-4. http://www.spc.int/OceanFish/Html/WCPFC/SC1/pdf/SC1_BI_WP_4.pdf

Kleiber, P. and J. Hampton. 1994. Modeling effects of FADs and islands on movement of skipjack tuna (*Katsuwonus pelamis*): estimating parameters from tagging data. Can. J. Fish. Aquat. Sci. 51:2642–2653.

Nielsen, A., K. Bibelow, M. Musyl and J. Sibert. 2005. Improving light-based geolocation by including sea surface temperature. *Fish. Oceanog*, In press. https://www.soest.hawaii.edu/tag-data/tracking/kfsst/

Schaefer, K.M., and D.W. Fuller. 2002. Movements, behavior, and habitat selection of bigeye tuna (*Thunnus obesus*) in the eastern equatorial Pacific, ascertained through archival tags. *Fish. Bull. U.S.* **100**:765–788.

Sibert, J.R., J. Hampton, D.A. Fournier and P.J. Bills. 1999. An advection-diffusion-reaction model for the estimation of fish movement parameters from tagging data, with application to skipjack tuna (*Katsuwonus pelamis*). *Can. J. Fish. Aquat. Sci.* 56: 925–938.

Sibert, J., and Hampton, J. 2003. Mobility of tropical tunas and the implications for fisheries management. *Mar. Pol.* **27**: 87–95.